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THE EFFECT OF NAVY AND AIR FORCE AIRCRAFT ENGINE TEST FACILITIES ON AMBIENT AIR QUALITY

DIRECTORATE OF ENVIRONICS

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FINAL REPORT FOR PERIOD JUNE 1975 TO JULY 1976

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AIR FORCE CIVIL ENGINEERING CENTER
(AIR FORCE SYSTEMS COMMAND)
TYNDALL AIR FORCE BASE
FLORIDA 32401

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An investigation of the air quality impact of DoD turbine engine test facilities was performed. Emissions and pollutant dispersion from test cells and aircraft at six DoD installations were predicted using a sophisticated computer model. Predicted pollutant concentrations are compared to ambient air quality standards and measured ambient values for hydrocarbons, oxides of nitrogen, and particulates. (cont)

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20. Jet engine test cells have no significant impact on air quality for any pollutant at any location studied. Test cell pollutant concentrations are considerably less than the levels generated by aircraft operations and well below measured ambient air quality levels in the areas studied. Ambient carbon monoxide and sulfur dioxide levels resulting from test cell emissions are insignificant. Control of any pollutants generated by test cells would not measurably improve ambient air quality.

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PREFACE

This report was prepared by the Air Force Civil Engineering Center, Tyndall Air Force Base, Florida, under Job order Number IEEV5A05. Portions of the data used in this study were collected by Stanford Research Institute and Woodward-Clyde Consultants.

This report documents the work completed between 1 June 1975 to 30 July 1976. Captain Bradford C. Grems III was project engineer and author, and Captain Dennis F. Naugle was coauthor.

The authors wish to thank Major Peter S. Daley, 1Lt Stephen C. Enzweiler, SMSgt Bennet B. Lamm, MSgt Richard H. Dalrymple, and MSgt Edward L. Orlowsky who have made major contributions to the report preparation or computer analysis.

This report replaces and supersedes AFCEC TM-76-7, "The Effect of Navy and Air Force Aircraft Engine Test Facilities on Ambient Air Quality."

This report has been reviewed by the Information Officer (IO) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Bradford C Grems III
BRADFORD C. GREMS III, Capt, USAF
Project Officer
Air Quality Research Division

Dennis F. Naugle
DENNIS F. NAUGLE, Capt, USAF, BSC
Project Officer
Air Quality Research Division

DONALD G. SILVA, Lt Col, USAF, BSC
Director of Environics

ROBERT E. BRANDON
Technical Director

ROBERT M. ITEN, Col, USAF
Commander

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THE EFFECT OF NAVY AND AIR FORCE AIRCRAFT ENGINE TEST CELLS ON AMBIENT AIR QUALITY

A. INTRODUCTION

An elaborate study of six installations was initiated to determine the contribution of jet engine test cells to the air quality surrounding DoD air bases. Three Air Force and three Naval installations were chosen for analysis because of their unusually large test cell operations. These locations were: the Naval Air Stations at Alameda, Norfolk, and Jacksonville, and Kelly, Tinker, and Nellis Air Force Bases. All of these except Nellis AFB are major turbine engine overhaul facilities.

There is no simple way to experimentally measure the air quality impact of specific sources such as engine test cells. To do so requires accurate determination of background levels of each pollutant, strict control over all other emission sources by the experimenter, exact duplication of meteorological conditions with and without operation of the source in question, and accurate measurements of pollutant concentrations over an extensive receptor network. Because of the difficulty, time (several years), and expense associated with measurement programs, the only viable alternative is modelling. The technical literature contains limited and often conflicting data on the accuracy of dispersion models. However, air quality modelling techniques are widely accepted and used. No better technique is available to relate complex emission sources to air quality levels.

An air quality assessment model (AQAM) was developed jointly by the Argonne National Laboratory and the USAF. It was designed to predict air quality in the vicinity of DoD air bases for five regulated pollutants: carbon monoxide, hydrocarbons, oxides of nitrogen, total suspended particulates, and sulfur dioxide. One can then compare impact of individual sources or classes of sources with one another and to health and welfare effects as characterized by ambient air quality standards.

AQAM consists of four functional elements:

a. The Source Inventory Program computes annual emissions from operational data for stationary, ground mobile, and aircraft sources. The operational data include not only simple quantitative emission information but also detailed emission-time correlations. These emission data are used in conjunction with relevant meteorological data to predict ambient air concentrations by either the Short-term or Long-term Dispersion Programs.

b. The Short-term Program calculates 1-hour average concentrations. Numerous meteorological parameters are considered including wind speed and direction, atmospheric mixing depth, and temperature. The combination of these parameters which result in the highest pollutant concentrations are defined as the "worst case" condition.

c. The Long-term Program calculates average concentrations for periods up to 1 year. The Long-term Program was not used because the Short-term hourly predictions indicated that annual averages would be insignificantly low.

d. The fourth element of AQAM is the Meteorological Data Program which is used to analyze climatological records at each specific location of interest. The probability of occurrence of various dispersion situations is computed for use in the Long-term Program.

This test cell study is part of a general AQAM study which covers stationary, ground mobile, and aircraft emission sources at thirteen military installations. Analysis and technical report preparation of the general AQAM study is still underway and will be completed in 1977. However, test cell and air operations data have been made available to analyze their contribution to the ambient air quality. Data in the general AQAM study relative to stationary and mobile sources may be of interest, but have no direct bearing on the test cell study. An additional study includes extensive ambient measurements at Williams AFB to determine the accuracy of AQAM predictions. Continuous ambient air quality data will be measured through June 1977 (or beyond if required) and will be followed by a statistical evaluation of the measured versus predicted comparisons.

B. AIR QUALITY ANALYSIS TECHNIQUES

The short-term (1-hour) period during which the highest pollutant emission rates occurred for each location was selected for analysis. Numerous combinations of meteorological conditions were selected to determine the "worst case" dispersion conditions likely to be encountered. For the purpose of this report the "worst case" was selected to be the worst combination of dispersion conditions that would occur twice yearly. These "worst case" conditions normally occur during the morning hours. Wherever possible, air quality during these worst case conditions were compared with available air quality measurements and standards. It should be emphasized that "worst case" conditions represent 1-hour conditions that might occur twice a year. Predicted levels do not represent average dispersion conditions throughout the year.

Predictions were made of the relative air quality impacts of test cells and aircraft. A comparison of the measured ambient air quality near the base and the predicted contribution from test cells was made. Measured ambient air quality information was obtained from the EPA Report 450/1-74-007 (October 1974) as indicated in Table 1. Existing

TABLE 1

HIGHEST MEASURED AIR QUALITY CONCENTRATIONS*

SOURCE: EPA REPORT 450/1-74-007, OCT 1974

	Particulates μg/m³	O_x μg/m³	HC μg/m³	CO μg/m³	NO_x μg/m³	SO_2 μg/m³
NAS ALAMEDA						
highest	120 (24)	431 (1)	N/A	16 (1)	212 (24)	13 (24)
2nd highest	105 (24)	372 (1)		15 (1)	-	10 (24)
				10.2 (8)	70 (annual)	
NAS JACKSONVILLE						
highest	130 (24)	N/A	N/A	N/A	96 (24)	1304 (24)
2nd highest	124 (24)				-	581 (24)
NAS NORFOLK						
highest	252 (24)	97 (1)	N/A	18 (1)	115 (24)	86 (24)
2nd highest	194 (24)	97 (1)		17 (1)	-	81 (24)
				9.8 (8)	-	
TINKER AFB						
highest	1367 (24)	440 (1)	N/A	49 (1)	205 (24)	9 (24)
2nd highest	1301 (24)	440 (1)		43 (1)	-	8 (24)
				24.4 (8)	-	
KELLY AFB						
highest	232 (24)	N/A	N/A	N/A	143 (24)	10 (24)
2nd highest	187 (24)	N/A	N/A	N/A	-	9 (24)
NELLIS AFB						
highest	213 (24)	504 (1)	N/A	N/A	112 (24)	10 (24)
2nd highest	182 (24)	438 (1)			-	2 (24)
					44 (annual)	

Note: ( ) - hours of time sampled. Both 1 and 8 hour standards apply to CO
N/A - information not available.

* No monitoring stations are located on the installation proper.

emission inventories for most areas were not in a form which could be encoded for AQAM computer modelling. Therefore, the highest measured values for pollutants in the vicinity of the base were used for comparison purposes.

Some correlations also were made with National Ambient Air Quality Standards (NAAQS) which are based on different averaging times (1, 3, 8, and 24 hours and annual) for different pollutants. Since meteorological conditions during successive hours of a specific averaging period cannot be determined with reasonable confidence, it is not possible at the present time to predict pollutant concentrations for direct comparison with the 3, 8, and 24-hour time standards.

Operational data were obtained by visiting each of the six sites modelled. The location of each runway, taxiway, runup stand, aircraft parking area, and fuel area were encoded to AQAM. Measured aircraft engine emission factors were used whenever possible. For those few engines where emissions were not measured, estimates were made based on measured emission factors of similar engines. Fuel spills and venting were also considered. Test cell operations reflected normal activity levels during the time periods chosen. Total annual aircraft operations were consolidated from records and their temporal distribution for monthly and diurnal cycles obtained from flying schedules and interviews with operations personnel.

No standard technique exists for the measurement of particulates from aircraft engines. Particulate emissions measured by the EPA Method 5 technique (as discussed in Section III-C-1) are comprised of two fractions: The "dry" fraction as measured by a filter catch and the "wet" or condensable material as measured by impingers. Under this technique "total particulates" refers to the sum of the wet and dry fractions. EPA method 5 is generally not used for aircraft engine emissions due to the slow and costly nature of data collection, and since some material would be condensed in the sampling train which would not be condensed in the atmosphere. Because of an inadequate data base of "total" particulate emission measurements, the "dry" fraction as reported from smoke number measurements is used as the basis for this AQAM analysis.

C. FINDINGS

1. ALAMEDA ANALYSIS

Detailed analyses of hydrocarbons, particulates, and NO_x are included in this section for NAS Alameda only. A thorough analysis of one location showed what aspects of the analysis of the remaining installations required emphasis. Alameda was chosen because of interest generated by a litigation concerning test cell plume opacity. SO_2 and CO from test cells were not analyzed in detail because they presented minimal potential for air quality degradation.

a. Hydrocarbons

A computer generated hydrocarbon isopleth (contour of equal pollutant concentration) resulting from an AQAM short-term (1-hour) analysis for test cells alone is shown in Figure 1. Maximum "worst case" hydrocarbon concentration predicted is 1.91$\mu g/m^3$. Figure 2 is a comparison between aircraft and test cell hydrocarbon ambient air quality impacts under "worst case" meteorological conditions. Test cells are only 2.6 percent of the aircraft air quality impact. It is clear from Figure 2 that jet engine test cells are negligible contributors to ambient air quality when compared to aircraft. Hydrocarbon ambient air concentrations generated by test facilities could not be compared to any measured hydrocarbon levels in the San Francisco Bay area since ambient measurements were not available in the October 1974 EPA Report.

b. Effect of Meteorological Conditions

Hydrocarbon concentrations resulting from jet engine test cell operations under different meteorological conditions are shown in Figure 3. Of the six stabilities checked, the "B" stability produces the single highest concentration of 1.9$\mu g/m^3$ from test cell sources. Similar high concentration patterns result with "B" stability for other pollutants.

c. Oxides of Nitrogen

An isopleth of 1-hour "worst case" concentrations of NO_x from test cells alone for NAS Alameda is shown in Figure 4. The maximum "worst case" contribution from test cells alone is 18$\mu g/m^3$. Figure 5 is a comparison of NO_x concentrations generated by aircraft and test cell operations. Test cell NO_x ambient levels are 58 percent of NO_x levels generated by aircraft operations. Note that the meteorological conditions which produce the peak test cell contribution are different from those producing the highest aircraft contribution. Since these conditions are mutually exclusive total pollution from test cells and aircraft together will always be substantially less than the sum of the two "worst cases" (for NO_x and other pollutants as well).

NO_x levels generated by test cells cannot be directly compared to measured NO_x ambient levels since ambient levels are based on 24-hour and annual arithmetic means. However, test cells under "worst case" meteorological conditions are less than 5 percent of the California 1-hour NO_x standard.

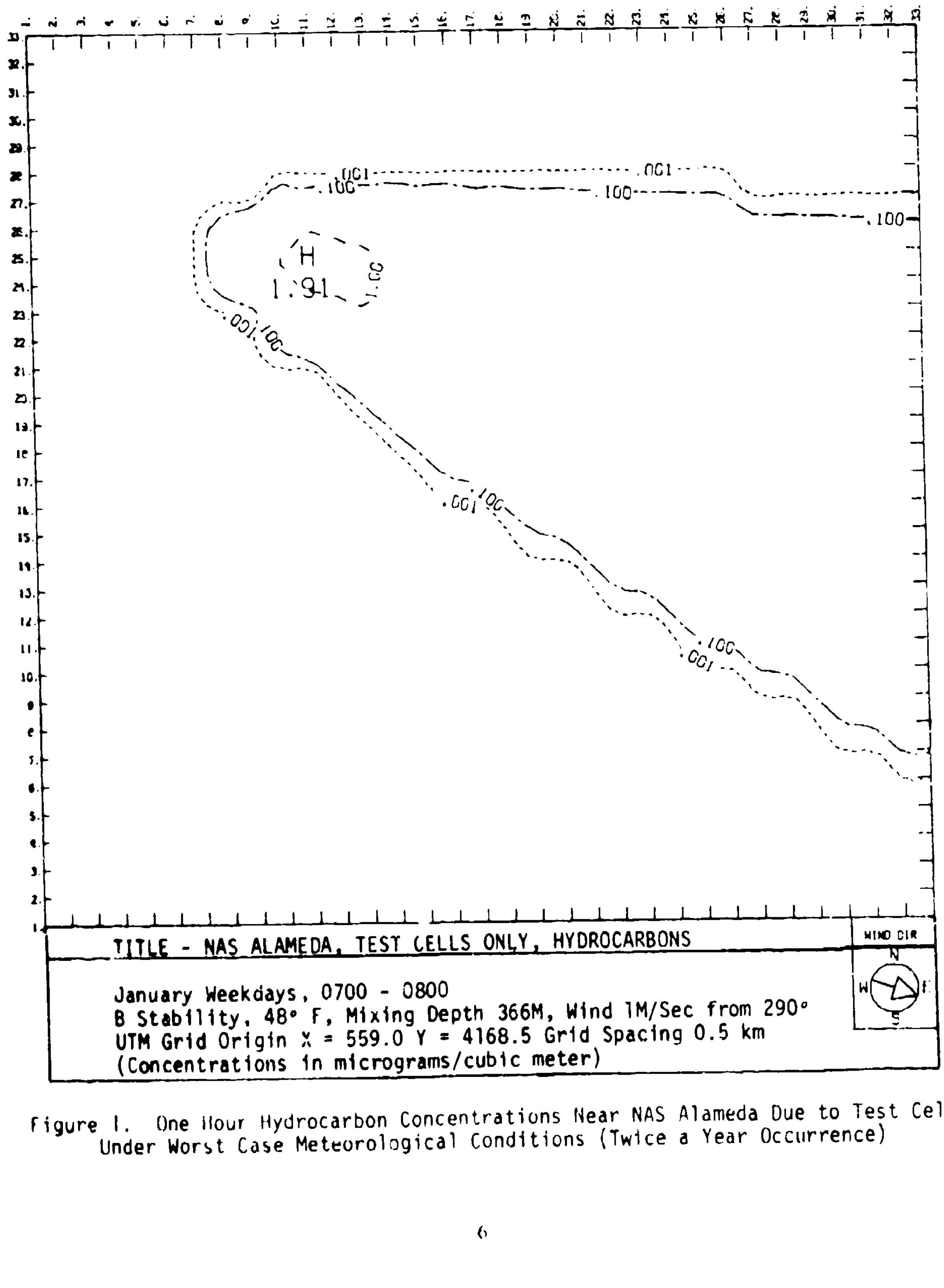


Figure 1. One Hour Hydrocarbon Concentrations Near NAS Alameda Due to Test Cells Under Worst Case Meteorological Conditions (Twice a Year Occurrence)

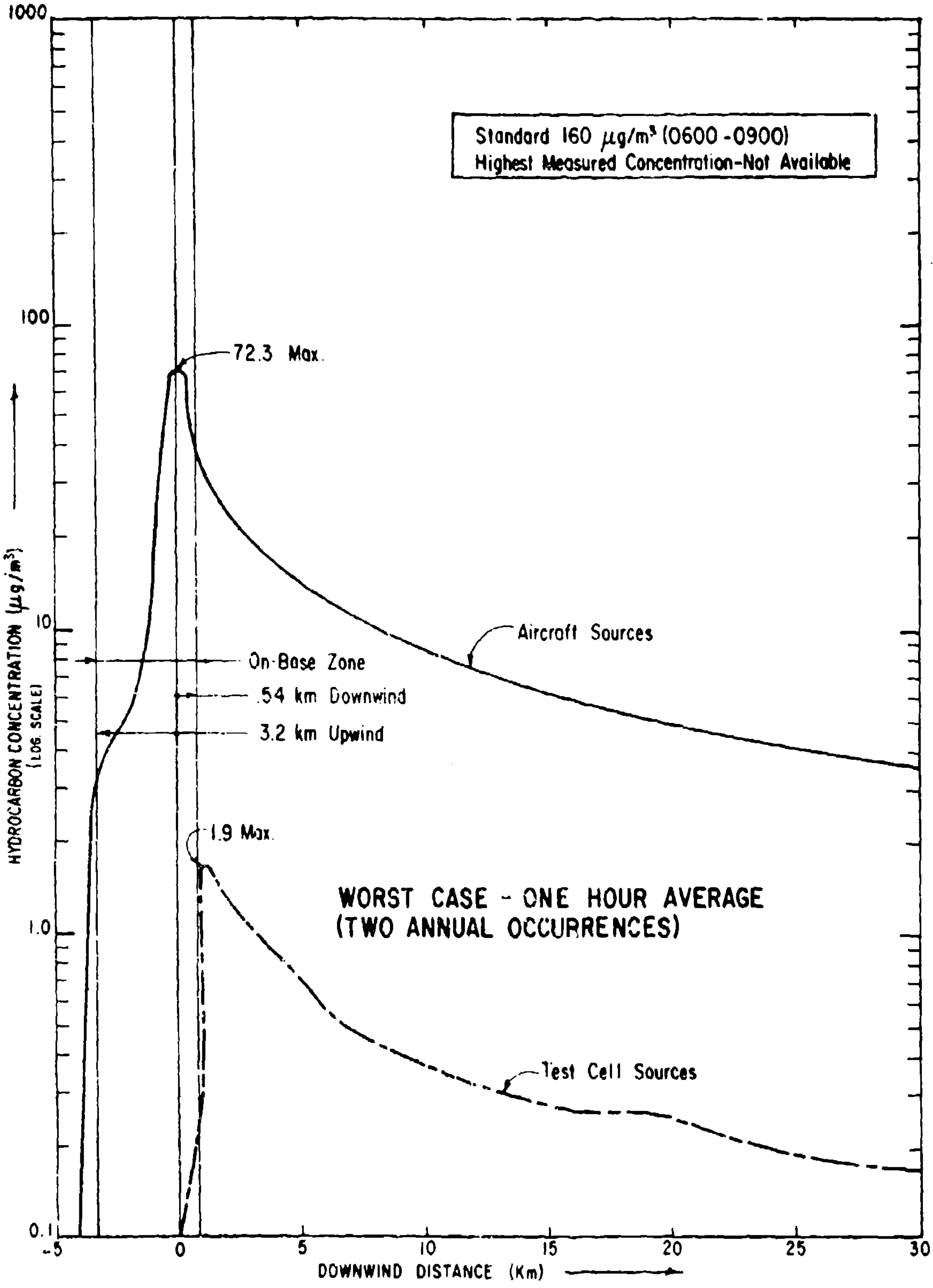


Figure 2. Worst Case Hydrocarbon Air Quality Predictions Near NAS Alameda

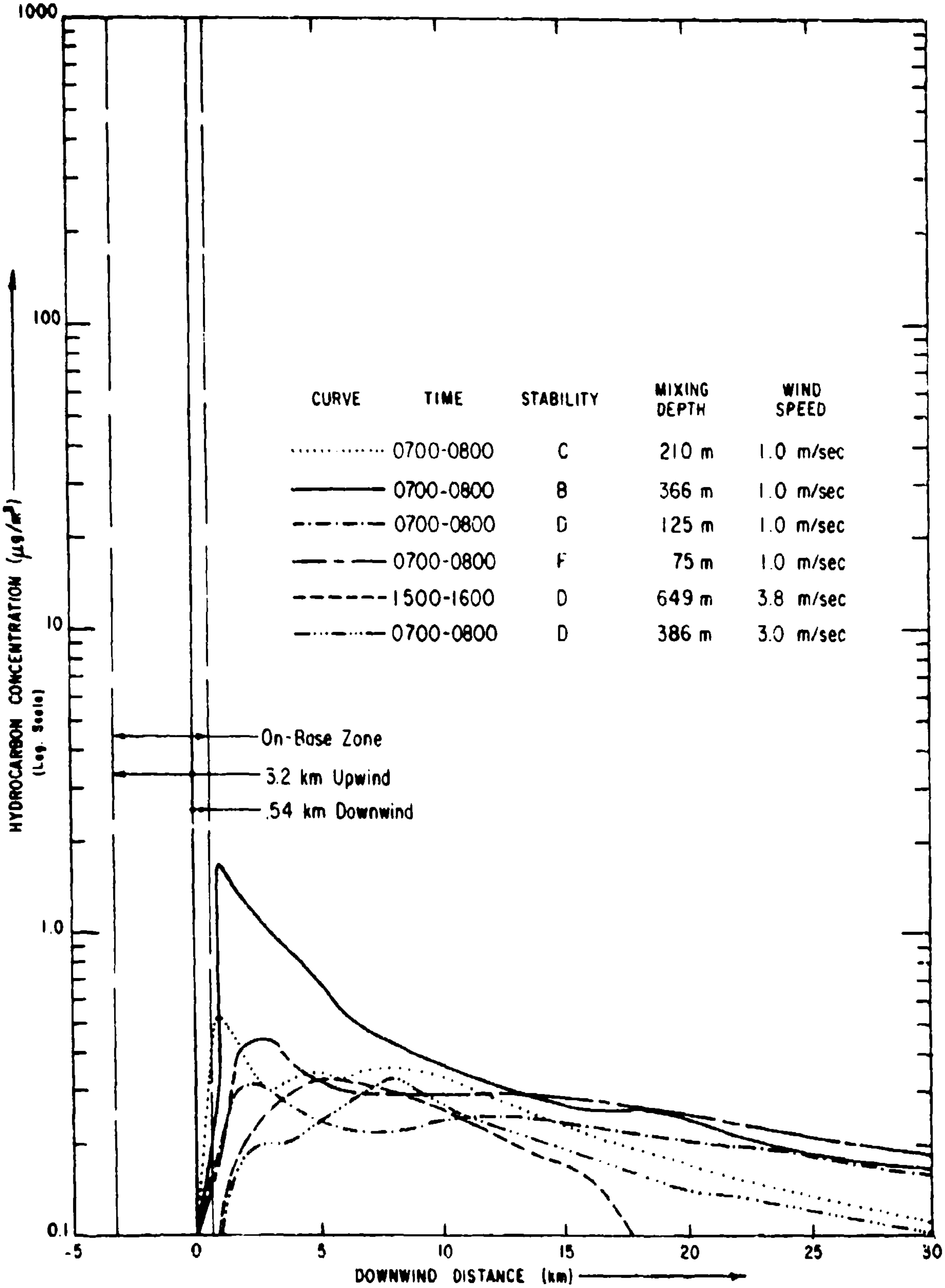


Figure 3. Effect of Meteorological Conditions on Hydrocarbon Concentrations Resulting from Alameda Engine Test Cells

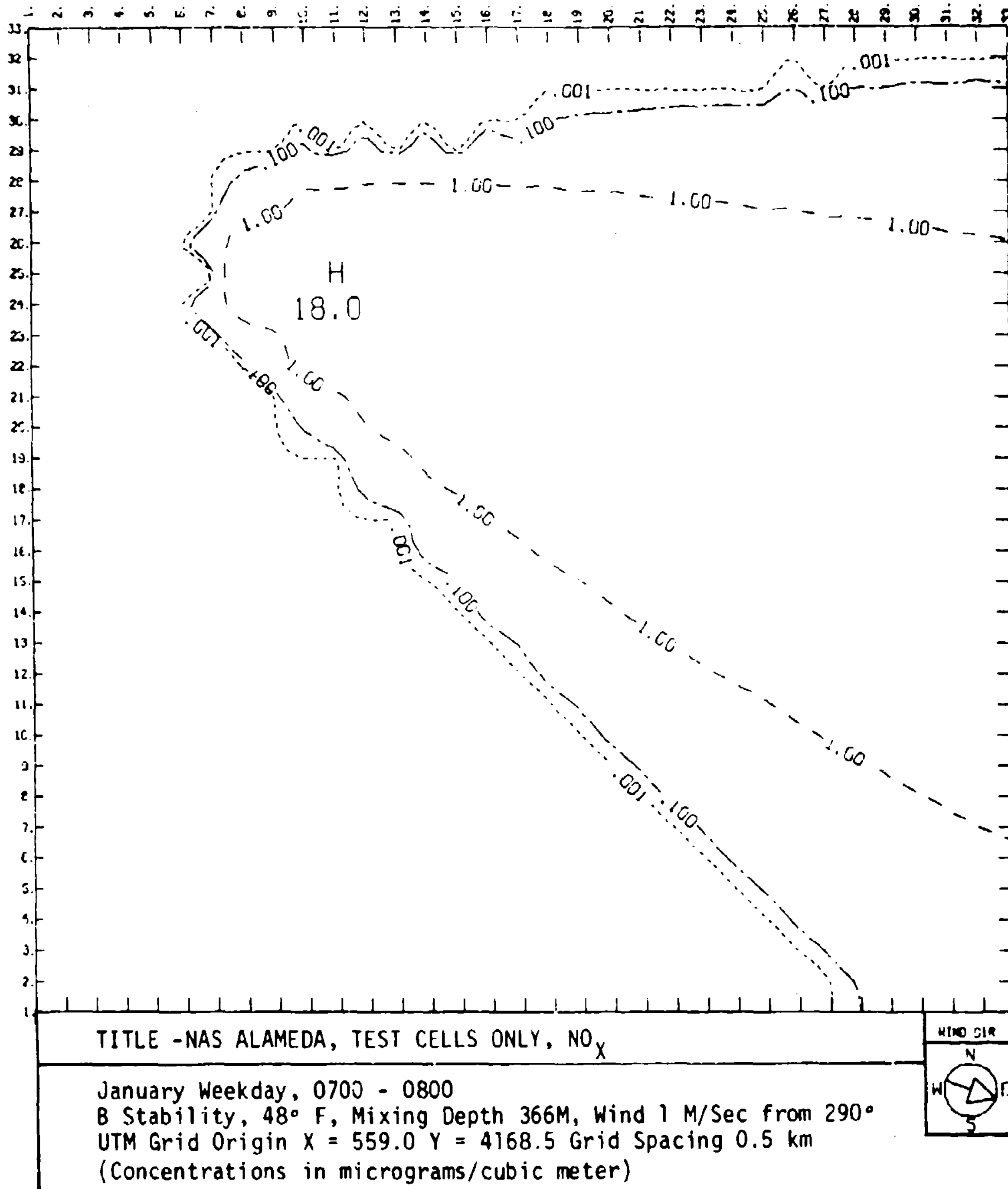


Figure 4. One Hour NO_X Concentration Near NAS Alameda Due to Test Cells Under Worst Case Meteorological Conditions (Twice a Year Occurrence)

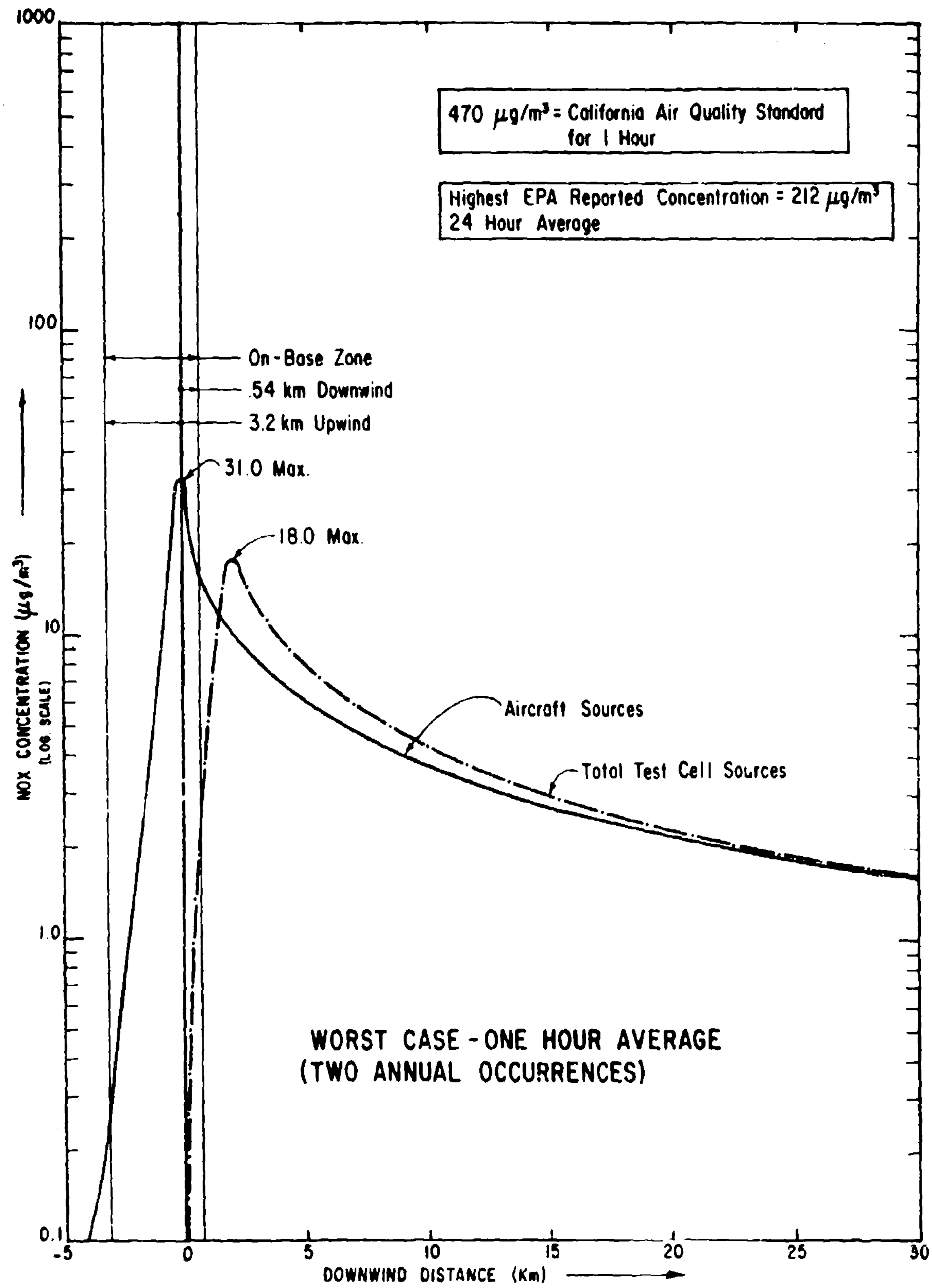


Figure 5. Worst Case NO_x Air Quality Predictions Near NAS Alameda

d. Particulates

Predicted "worst case" 1-hour suspended particulate matter concentrations are shown in Figures 6 and 7. Figure 6 is a computer-generated isopleth for test cells predicting a maximum particulate level concentration of 0.7μg/m³. Figure 7 is a comparison of aircraft and test cell particulate concentrations. Predicted test cell concentrations are one-third the aircraft concentrations. One-hour "worst case" concentrations from test cells are well below the maximum 24-hour particulate level measurements (120μg/m³) made in the bay area (Table 1). Thus, if 1-hour "worst case" operational and meteorological conditions prevailed for 24 hours, cells would still be only 0.6 percent of the highest measured air quality value.

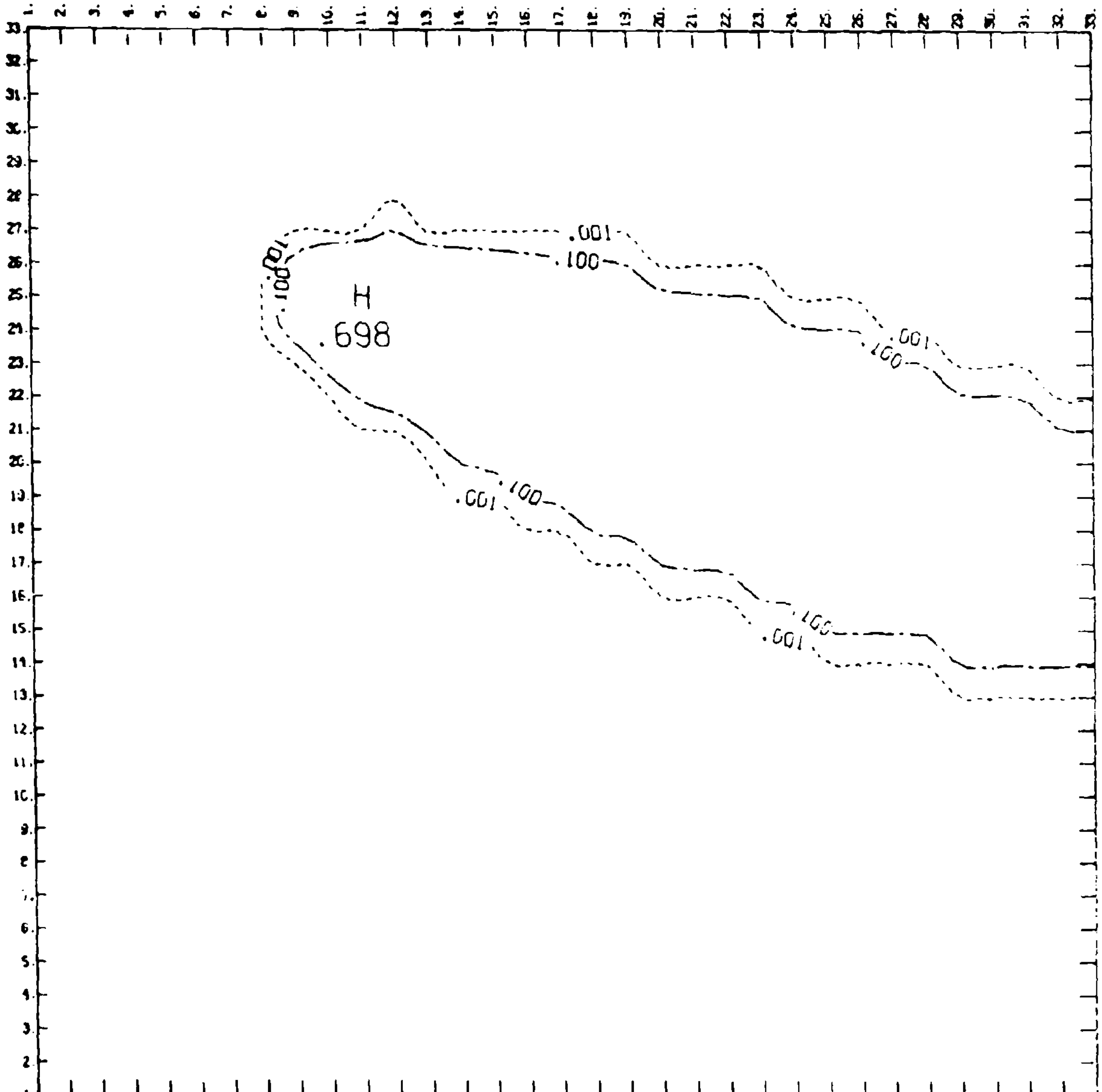
e. Carbon Monoxide (CO) and Sulphur Dioxide (SO_2)

Carbon monoxide and sulphur dioxide ambient air impact were not analyzed since test cells alone are insignificant contributors to ambient levels of CO and SO_2. Levels of CO and SO_2 generated by the cells would be below the detection threshold of ambient air measuring systems. The absolute maximum predicted SO_2 concentration from test cells is 1.4μg/m³ versus a minimum required sensitivity of 25μg/m³ for the EPA reference method for determining SO_2 in the atmosphere. The maximum predicted CO concentration is 9.9μg/m³. The EPA reference method does not specify a minimum sensitivity for measuring CO; however, it is in the mg/m³ range.

2. ANALYSIS OF OTHER BASES

a. Hydrocarbons

The maximum 1-hour "worst case" ambient air hydrocarbon concentrations from test cells alone for all installations studied, are shown in Table 2. In all instances the test cell levels are below aircraft levels by a factor of 20 or more. Direct comparison of predicted test cell hydrocarbon ambient levels to the National Ambient Air Quality Standards is difficult since the ambient standard is based on a 3-hour period whereas input into the AQAM can be accomplished for 1-hour "worst case" conditions only. However, in an attempt to quantify test cell ambient level contributions toward the NAAQS levels, one could assume that "worst case" conditions would prevail for a 3-hour time period. If this is done, the test cell air quality levels are less than 3 percent of the National Standard at all installations studied. In actuality, "worst case" meteorological conditions would not prevail over this extended period of time, and test cell air quality impact averaged over the 3-hour time period would be less than the 3 percent of the National Ambient Air Quality Standard levels shown in Table 2.



TITLE - NAS ALAMEDA, TEST CELLS ONLY, PARTICULATES

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B Stability, 48° F, Mixing Depth 366M, Wind 1 M/Sec from 290°
UTM Grid Origin X = 559.0 Y = 4168.5 Grid Spacing 0.5 km
(Concentrations in micrograms/cubic meter)

Figure 6. One Hour Particulate Concentrations NAS Alameda Due to Test Cells Under Worst Case Meteorological Conditions (Twice a Year Occurrence)

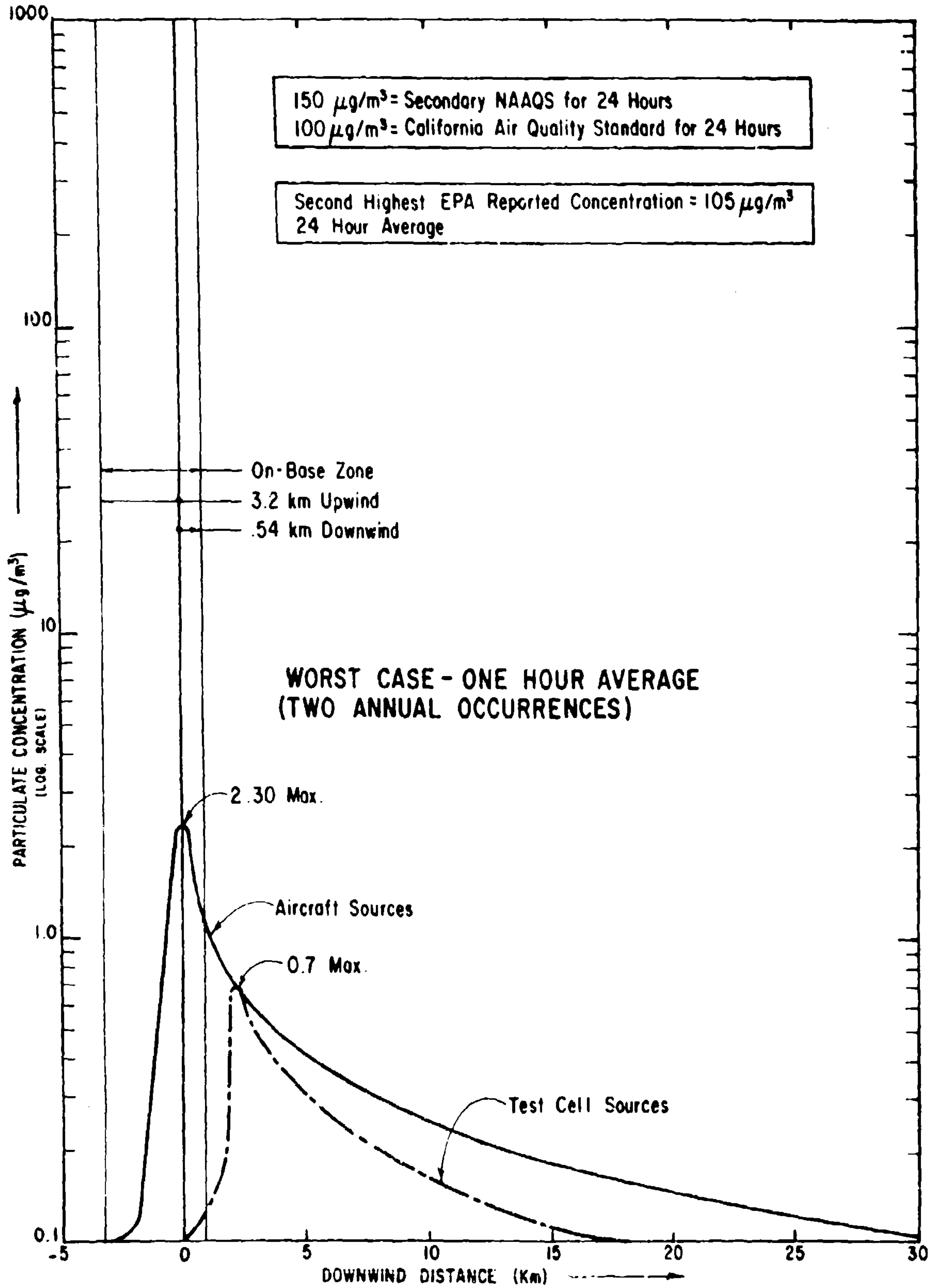

Figure 7. Worst Case Particulate Air Quality Predictions Near NAS Alameda

TABLE 2

TEST CELL AIR QUALITY IMPACT: HYDROCARBONS

	NAS ALAMEDA	NAS JACKSONVILLE	NAS NORFOLK	TINKER AFB	KELLY AFB	NELLIS AFB
Test Cell Maximum Prediction ($\mu g/m^3$ for the "worst case" 1 hour)	1.9	3.4	1.3	5.3	1.1	.04
Aircraft Maximum Prediction ($\mu g/m^3$ for the "worst case" 1 hour)	72	76	220	1903	515	431
Highest Ambient Measurements ($\mu g/m^3$ for a 6-9AM period)	N/A	N/A	N/A	N/A	N/A	N/A
National Ambient Air Quality Standard ($\mu g/m^3$ for the 2nd highest 6-9AM period)	160	160	160	160	160	160
Test Cell Contribution[(1)] (% of highest measurement)	N/A	N/A	N/A	N/A	N/A	N/A
Max Test Cell Impact[(2)] (% of Air Quality Standard)	<1%	<2%	<.8%	<3%	<.7%	<.03%

Footnotes:

(1) The test cell contribution relative to measurements cannot be computed due to the lack of measured data.

(2) The maximum test cell impact is computed by: $\frac{\text{Max test cell prediction - 1 hour}}{\text{Ambient Air Quality Standard - 3 hour}}$

Three hour predictions are not available but would make the % impact less than (<in table) the impact presented.

b. Oxides of Nitrogen

NO_x levels from test cells alone under 1-hour "worst case" conditions are shown in Table 3. All are below aircraft levels and well below the 1-hour California Air Quality Standard level of 470$\mu g/m^3$. The highest predicted concentration represents less than 4 percent of this value.

c. Particulates

The maximum 1-hour "worst case" concentration of particulates from all bases studied are shown in Table 4. Test cell predicted ambient levels from all bases studied are below aircraft particulate levels by a factor of 3 or more. The highest 1-hour predicted test cell contribution is less than 1.3 percent of the highest 24-hour ambient measurement. Comparison with ambient air quality standards is difficult since the ambient air quality standard for particulate matter is based on a 24-hour sampling period. If one assumes "worst case" meteorological conditions are constant for 24 hours, which in reality would not occur, the particulate levels from test cells are still less than 2 percent of the NAAQS level. In reality the levels over 24 hours from test cells alone would be less than the percentages shown in Table 4.

D. CONCLUSIONS

Jet engine test cells have no significant impact on air quality for any pollutant at any location studied. Test cell pollutant concentrations are considerably less than the levels generated by aircraft operations and well below measured ambient air quality data in the areas studied. Direct comparison of predicted test cell concentrations to ambient air quality standards is difficult due to differences in averaging times (1-hour predictions versus 3, 8, or 24-hour periods for standards). Nevertheless, predicted air quality concentrations under the "worst case" single hour conditions were only a small fraction (1/1000 to 1/25) of standards associated with various longer averaging times. Ambient carbon monoxide and sulphur dioxide levels resulting from test cell emissions are insignificant. Control of any pollutants generated by test cells would not measurably improve ambient air quality.

TABLE 3

TEST CELL AIR QUALITY IMPACT: OXIDES OF NITROGEN

	NAS ALAMEDA	NAS JACKSONVILLE	NAS NORFOLK	TINKER AFB	KELLY AFB	NELLIS AFB
Test Cell Maximum Prediction ($\mu g/m^3$ for the "worst case" 1 hour)	18.0	13.8	5.9	19.6	5.2	.9
Aircraft Maximum Prediction ($\mu g/m^3$ for the "worst case" 1 hour)	31	148	134	247	57	150
Highest Ambient Measurement ($\mu g/m^3$ for a 24 hour period)	212	96	115	205	143	112
California Ambient Air Quality Standard ($\mu g/m^3$ for a 1 hour period)	470	470	470	470	470	470
Test Cell Contribution(1) (% of highest measurement)	<8%	<14%	<5%	<10%	<4%	<0.8%
Max Test Cell Impact(2) (% of California Air Quality Standard)	<4%	<3%	<1%	<4%	<1%	<0.2%

Footnotes:

(1) The test cell contribution is computed by: $\frac{\text{Max test cell prediction - 1 hour}}{\text{Highest Ambient Measurement - 24 hour}}$

Single hour measurements are not available but would cause the contribution to be less than (<) indicated in table.

(2) The *maximum* test cell impact is computed by: $\frac{\text{Max test cell prediction - 1 hour}}{\text{Ambient Air Quality Standard - 1 hour}}$

The highest prediction due to test cells is used. Concentrations at all other locations would be less than (<in table) the impact presented.

TABLE 4

TEST CELL AIR QUALITY IMPACT: PARTICULATES

	NAS ALAMEDA	NAS JACKSONVILLE	NAS NORFOLK	TINKER AFB	KELLY AFB	NELLIS AFB
Test Cell Maximum Prediction ($\mu g/m^3$ for the "worst case" 1 hour)	.7	.6	2.5	2.7	1.0	0.2
Aircraft Maximum Prediction ($\mu g/m^3$ for the "worst case" 1 hour)	2.3	10.9	10.4	21	29	35
2nd Highest Ambient Measurement ($\mu g/m^3$ for a 24 hour period)	105	124	194	1301	187	182
National Ambient Air Quality Standard ($\mu g/m^3$ for the 2nd highest 24 hr period)	150	150	150	150	150	150
Test Cell Contribution(1) (% of highest measurement)	<.7%	<0.5%	<1.3%	<.2%	<.5%	<.1%
Max Test Cell Impact(2) (% of Air Quality Standard)	<0.5%	<.4%	<2%	<2%	<.7%	<.1%

Footnotes:

(1) The test cell contribution is computed by: $\dfrac{\text{Max test cell prediction - 1 hour}}{\text{Highest Ambient Measurement - 24 hour}}$

Average 24 hour predictions are not available but would cause the contribution to be less than (<) indicated in table.

(2) The maximum test cell impact is computed by: $\dfrac{\text{Max test cell prediction - 1 hour}}{\text{Ambient Air Quality Standard - 24 hour}}$

The actual impact is less than (<) indicated because a 1 hour prediction is worse than a 24 hour average.

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SAMSO/DEC	1
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AMD/RDU	1
ADTC/DLOSL	2
AFCEC/XR	2
AFCEC/EV	1
USAF Rgn Civ Engrg/Title Bldg	1
USAF Rgn Civ Engrg/SF	1
USAF Rgn Civ Engrg/Dallas	1
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USAFSO/DEE	1
1 Med Service Wg/SGB	1
USAF Hosp/SGPM	1
AFCEC/WE	1
DDC/TCA	12
Def Rsch & Engrg/AD(E&LS)	1
OASD/(I&L)ES	1
USA Environ Hygn Agcy	1
Ch of Engrg/ENGMC-RD	1
Ch of R&D/DARD-ARE-E	1
Environ Protection Div/OP-45	3
NCEL/Code 25111	1
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NJAG/Dept of the Navy	1
Naval Facilities Engrg Comd/VA	2
Chief of Naval Material	2
NFEC/San Diego CA	2
Nav Air Sys Comd	5
Nav Air Propulsion Test Ctr	1
Naval Air Rework Facility/CA	1
NFEC/San Bruno CA	5
AUL (AUL-LSE-70-239)	1
SAF/GC	1
SAF/ILE	1
HQ USAF/PREV	5

INITIAL DISTRIBUTION (CONCLUDED)

HQ USAF/RDPN	1
AFSC/DL	1
AFSC/DEP	1
AFLC/DE	1
AFLC/DEV	1
AFLC/MAJ	1
CINCSAC/DEPP	1
ATC/DEP	1
AFCEC/EVD	1
AFCEC/EVA	5